CHIPS: a database of historic fish distribution in the Seine River basin (France)

by

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Abstract. – The evolution of freshwater fish distribution and long term change in the composition of fish assemblages in rivers are currently the subject of various ecological studies. These studies usually focus on a relatively short range of time, rarely exceeding the last few years. However, this interval is far too short to understand in what extent human societies impact their environment. In order to study interactions between human activities and rivers and their fish assemblages over longer periods of time, we searched the historical record to retrieve information on fish and their distribution in streams in the Seine River basin. A database, named CHIPS (Catalogue HIstorique des Poissons de la Seine), was developed to organize the information. In a first step, we focused data collection on the last two centuries. We present preliminary qualitative analyses using selected parts of this database. They show notably that the distribution area has changed for some species and that a substantial evolution in fish assemblages has occurred in certain rivers since the beginning of the 19th century.

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Résumé. – CHIPS : une base de données historiques sur les poissons du bassin de la Seine.

L'évolution de la distribution spatiale et les changements à long terme des peuplements de poissons en cours d'eau sont l'objet de divers travaux en écologie. Ces travaux se concentrent généralement sur des périodes de temps relativement courtes, excédant rarement les dernières années. Cet intervalle de temps apparaît trop court lorsque l'on cherche à comprendre comment les sociétés humaines impactent leur environnement. Pour aborder les interactions entre les activités humaines et les cours d'eau et leurs peuplements de poissons sur de plus longues périodes de temps, nous avons développé une base de données dénommée CHIPS (pour "Catalogue HIstorique des Poissons de la Seine"). Elle rassemble les informations collectées dans les documents anciens sur les cours d'eau et leurs peuplements ichtyologiques dans un bassin hydrographique donné, ici le bassin de la Seine. La collecte de données a, dans un premier temps, été restreinte à la période de temps correspondant aux deux derniers siècles. Nous présentons ici des analyses préliminaires qualitatives obtenues à partir de l'exploitation de segments de cette base. Elles révèlent notamment que la distribution spatiale de certaines espèces a fortement évolué et qu'il existe une évolution significative de la composition des peuplements depuis le 19e siècle dans certains cours d'eau.

Most studies of river ecology and particularly of fish assemblages focus on spatial issues and frequently neglect temporal ones. In those studies addressing temporal issues, the time period studied is generally short, rarely exceeding the few last years when fish sampling methods were more or less standardized. This is often the result of limited access to longer term data sets and to the unavoidable problem of the heterogeneity of data from historical time periods. However, long term temporal studies are needed, notably because ecosystem management and environmental policies are increasingly oriented to long term approaches. For example, the European Water Framework Directive mandates aquatic ecosystems management measures to be implemented over nearly thirty years (Hering *et al*., 2010). Moreover, global change and its impacts on river ecosystems and on their biodiversity must be addressed at a scale of at least several decades or even a century (Ducharne *et al*., 2007; Logez and Pont, 2013).

Several authors have proposed a statistical approach based on present-day, fish distribution data sets to modelling the ecological niche of species in order to predict the consequences of long term environmental change on riverine fish distribution and their assemblages. By running these models under probable future, environmental conditions, they have tried to assess how fish assemblages might react (Lassalle and Rochard, 2009; Buisson *et al*., 2008; Logez and Pont, 2013).

These fish assemblages studies over a long range of time (1) assessed the natural and anthropogenic causes of fish distribution change during the historical time period, (2) provided original information on the rate of assemblage change in given contexts, and (3) tested the models mentioned above, as well as encouraging interdisciplinary discussion about the evolution of biodiversity.

Long-term approaches are not often applied to European rivers (but see Lelek, 1989; Keith, 1998; Wolter *et al*.,

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2000 or Carrel, 2002). A recent publication on American rivers (Rinne *et al*., 2005) presents examples of the historical change in fish assemblages in 27 river systems. However, with few exceptions [see Gammon (2005), for the Wabash River over two centuries], most studies address change in fish assemblages over only the past few decades or only supply a compilation of native and non-native species to illustrate major changes.

To find information on long term changes in fish fauna and assemblages, we studied historical archives and older scientific publications dealing with fish (and crayfish) and their distribution in the Seine River basin (France). Previous historical studies provided a good basis for our work (Belliard *et al*., 1995; Boët *et al*., 1999; Costil *et al*., 2002; Rochard *et al*., 2009). They focus on global modifications of fish fauna and, to a lesser extent, on the local evolution of fish communities, especially in the Seine River estuary. A database named CHIPS (Catalogue HIstorique des Poissons de la Seine) was developed to organize the historical information. As a beginning, we focused data collection on the period from the end of the 18th century to the mid-20th century. The end of the 18th century corresponds to the beginning of the Industrial Revolution during which several major anthropogenic impacts on rivers and fish were observed. First, this paper presents the database. We outline the types of sources consulted and the data record fields used, and we give some general information about the extent of the dataset currently available. Second, to illustrate how this database might contribute to future research, we briefly present the results of a preliminary qualitative analysis.

MATERIAL AND METHODS

Sources

The search for historical fish data was done at the French National Archives (Archives nationales) in Paris and in Fontainebleau, and the departmental archives of Eure and Yonne (in Evreux and Auxerre Prefectures, respectively), and in different institutes and university libraries, such as the Muséum national d'Histoire naturelle (MNHN) in Paris, the Sainte-Geneviève Library, and the French National Research Institute of Science and Technology for Environment and Agriculture (Irstea, Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture). We also found documents on Gallica, a digital library created by the French National Library (BnF, Bibliothèque nationale de France).

We distinguished between different categories of documents depending on their origin and content. The first category includes handwritten (and also typewritten) documents. A large part of these come from official sources, usually government archives or institutions in charge of the national planning (e.g. the government departments of Ponts et Chaussées and Eaux et Forêts). These documents are normative (legislative texts, rules, etc.), administrative (reports, correspondence, etc.) or technical documents (civil engineering plans and projects). We looked at all individual correspondence. The latter should be used with caution due to their possibly subjective nature (e.g. in the case of complaint). A second category includes numerous historic documents, such as naturalists' notebooks and scientific literature, published between the end of the 18th and the beginning of 20th centuries.

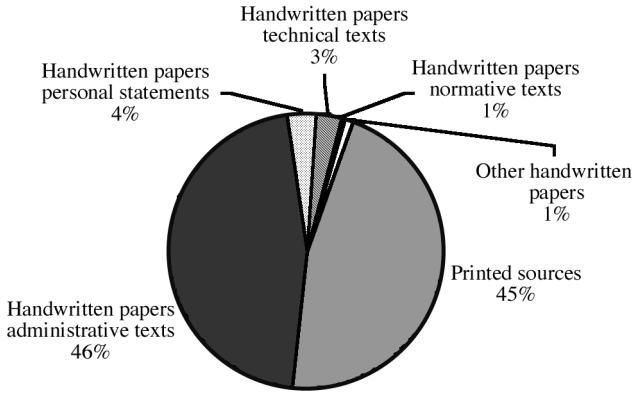

Figure 1. - Historical data: origin and percentages for observations from all sources.

In total, we consulted several thousands of documents, but few of them provided useful information. It should be noted that information on rivers in general (i.e. structures on rivers such as dams, locks, water-mills, as well as rivers maps, etc.) was quite easily found in the historical record, but information on fish is much more difficult to find. There is no research guide that references all the historical sources on fish. Of the thousands of documents consulted, only 282 documents provided relevant information on the presence of fish in rivers or ponds (Fig. 1). About 45% are printed documents and the rest are handwritten papers. Administrative texts (e.g. reports) represented the greatest part of the handwritten documents (130 documents). These documents provided information about fishing legislation, fishing limits, river restocking, and fish protection. Ten personal statements, eight technical texts, and two normative texts, that include information on fish, were also found in the handwritten papers.

Examples of sources

To illustrate what kinds of sources were found, we chose two examples of public inquiries led by the Ponts et Chaussées department. In 1879, the Senate created a commission to propose rules to limit fish depletion and to ensure restocking. This commission collected information on river and migratory fish stocks, best restocking practices, and evalua-

Table I. - Major information entered into the CHIPS database.

Data identification
Code (numeric code automatically generated)
Taxa
Vernacular name (name as noted in the source)
Detail: French local name is recorded
Latin name (name as noted in the source)
Species code (code used by Onema, it allows sorting of species recorded under different names)
Hydrographic location
Watershed (in this case: Seine basin)
Water body name (stream name)
Water body (river, pond, canal, other)
Section type (unspecified, spawning ground, growth area, transition area, migration upstream limit)
Hydrographic detail (free field)
Place name 1 (free field; when **Place name 2** is completed it corresponds to upstream location)
Place name 2 (id.: downstream location)
Administrative information
Region (Bourgogne, Centre, Île-de-France, Haute-Normandie, Champagne-Ardenne, Picardie)
Department (free field: department number)
City (free field)
Administrative detail (free field)
Date
Observation date (date is noted under format dd/mm/yyyy)
Detail: when no date is specified, we gave the publication date; when only the year is given, we recorded the date under January 1st of the year
Temporal detail (exact date, exact month and year, exact year, some years, decades, exact century)
Date type (exact date, period, date of knowledge, publication date, first observation, last observation)
Observation features
Presence (present or absent)
Detail: species are noted "absent" when it is specified in the source
Abundance (free field: as noted in the source)
Introduction/Restocking (free entry + detail)
Extinction (extinction signalled or not)
Biometry / Stocks / Health conditions / Ecology Information indicated with check boxes + detail in "other information"
Other information (free field: every data that provides additional information, in particular details about species biometry, fishing stocks, restocking, spawning date, etc.)
Observation type (catch/direct observation, inquiry/summary, story or account)
Detail: - catch/direct observation: author account - inquiry/summary: in the case of inquiry led by the one who has fished or catches whom the author have heard previously. We mentioned in the field "Other information" if it was a catch or an observation. - story or account: in case of an account told to the author and which could have not been checked.
Observation quality (correct data, partially correct data, possible doubt, incorrect data)
Detail: in case of story or account, the observation quality is noted as "partially accurate" or "possible accuracy"
Source
Source reference (link with a bibliographic Endnote database including all appropriate fields: author name, article/book/journal title, publication date, etc. For sources from government archives, the archive box reference is also noted.)
Page number
Other
Confidentiality (check box in case of confidential source and difficulty of obtaining access to the document)

tion measures to maintain or improve river fish production[1]. A questionnaire was sent by the Ministry of Public Works to government agency personnel, particularly to the Ponts et Chaussées engineers. It included twenty-four questions about rivers divided into three themes: (1) statistics: abundance, species occurrence, species reduction, fish numbers; (2) causes of depletion: direct human causes (fishing and poaching); industrial, climatic, and accidental causes; inadequate legislation and/or regulation; and (3) restocking: measures under consideration, site selection, etc.

In 1889, the Ministry of Public Works sent an additional questionnaire to the French departmental governments[2] regarding change in the legislation on Atlantic salmon fishing. It included questions about: observation of the different kind of salmon; migration periods; number of migrations; upstream limit of migrations; obstacles limiting migration (dams, factories, traps, water quality, etc.); location of fish passages (passage type, size) and fish passage effectiveness; spawning grounds and spawning dates; fish condition before and after spawning (size, colour, state of health, etc.); times when juveniles were observed, the length of their stay in the river before migrating to the sea; local names of juvenile fish; size and weight of fish caught; different methods of fishing; fish markets; if the opening and closing dates for fishing differed from those set by decree.

Database structure

The data collected from the different historical sources were managed in the database CHIPS (Catalogue HIstorique des Poissons de la Seine). The database is built with "fish observation" as the key entry field and is the presence or absence of a given species (or taxa) in a known location with an observation date. In order to limit the effect due to heterogeneity of the historical documents, we paid particular attention to assessing the accuracy and the quality of the observations (Tab. I).

The data fields were chosen to fit the information required for distribution and assemblage quality analyses. The fields are taxa identification, hydrographical references and geographical information, temporal information, biological and ecological information, type of data, and data reliability.

Taxa identification

For each observation, we used the vernacular and Latin fish names given in the historical sources and assigned a taxonomic code. The taxonomic codes are based on those used by Keith (1998) and by the Office national de l'eau et des milieux aquatiques (ONEMA, the French National Agency for Water and Aquatic Environments). Each code is linked to a taxon, generally at the species level, following the European fish list from Kottelat and Freyhof (2007). As a result, fish that have been recorded with different local or scientific names can be easily sorted. For some genera, the recent list by Kottelat and Freyhof (2007) distinguishes several species that were initially listed as a single species in older publications (e.g. in the genera *Cottus*, *Gobio* and *Phoxinus*). In CHIPS, this is not a problem because, in the Seine basin, these genera are currently represented by a single species and we have no reason to believe that this situation has changed during the past two centuries. For example, the former *Cottus gobio* (Linnaeus, 1758) is now differentiated into about ten different species distributed across Europe, but only one species, *Cottus perifretum* Freyhof, Kottelat & Nolte, 2005, is present in the Seine basin (Keith *et al*., 2011).

For species identified by obsolete Latin names, we used FishBase, which provides synonyms for scientific names. Additionally, we developed a list of local fish names used during the 19th century and the beginning of the 20th century and we included the corresponding vernacular English and French names next to the scientific names (Tab. II). This list is largely based on an earlier list developed in 1890 by the Commission in Charge of River Fishing Control[3] and supplemented by Belloc's work (1898).

The fish taxonomic designation depends on the accuracy of the observation by the observer and on the understanding by the document's author (not necessarily the same person). In some cases, we could only determine the genus or a complex of species. In these cases, we added supplementary codes. For some cyprinids, especially some "carps", which could not be clearly identified, we used the code "CYPR", which includes for instance *Cyprinus kollarii* (Heckel, 1836) and *C. buggenhagii* (Bloch, 1784) and refers to different cyprinid species and hybrids that are not easily differentiated. For the Petromyzontidae, 39 references could not be assigned a genus. These fish were recorded under their local names using the code "PETR". For crayfish, 112 observations were recorded under the code "ECRE" and seven observations of Mugilidae were entered under the code "MUGI". We use the code "TRX" to group together all the trout for which the genus was not known (frequently only the labels "trout" or "salmon trout" were used in the documents and probably referred to resident and migratory forms of *Salmo trutta* (Linnaeus, 1758). In some historic sources, other salmonid species, such as *Salvelinus fontinalis* (Mitchill, 1815) and *Oncorhynchus mykiss* (Richardson, 1836) may have been identified as "trout" or "salmon trout". We could not assign any taxonomic code to 76 observations.

[1] AN F14 13600: Ponts et Chaussées answers to the Senate commission inquiry for the rivers restocking (1879, July 29th), 1879.

[2] AN F14 13603: Ponts et Chaussées answers to the ministerial circular (1888, December 27th) about legislation on Atlantic salmon fishing, 1889.

[3] AN F14 13606: *Principales espèces fluviales et leurs noms locaux* Commission in charge of river fishing control report, 1890.

Table II. - Species recorded with family names, English and French common names, French local names (families, species names and French common names are mainly based on Keith *et al*., 2011; English common names are from Fishbase and French local names are from Belloc, 1898).

Species	Family	English common name	French common name	French local name
Petromyzon marinus (Linné, 1758)	Petromyzontidae	Sea lamprey	Lamproie marine	Anguille, Lampresse, Grande lamproie
Lampetra planeri (Bloch, 1784)	Petromyzontidae	European brook lamprey	Lamproie de Planer	Chatouille, Lamproie sucet, Petite lamproie
Lampetra fluviatilis (Linné, 1758)	Petromyzontidae	River lamprey	Lamproie de rivière	Lamproie fluviatile, Petite lamproie, Chatouille, Sept-œil, Sept-œil rouge, Sept-œil aveugle
Acipenser sturio (Linné, 1758)	Acipenseridae	Sturgeon	Esturgeon	Atargeon
Anguilla anguilla (Linné, 1758)	Anguillidae	European eel	Anguille	Cibèle, Cive, Civèle, Civelle
Alosa alosa (Linné, 1758)	Clupeidae	Allis shad	Grande alose	Hareng alose, Clupée alose
*Alosa fallax (*Lacepède, 1803)	Clupeidae	Twaite shad	Alose feinte	Finte, Caluyau, Feinte œuvrée, Clupée feinte, Pucelle
Tinca tinca (Linné, 1758)	Cyprinidae	Tench	Tanche	Tinche, Tenca, Tenco, Beurotte
Leucaspius delineatus (Heckel, 1843)	Cyprinidae	Belica	Able de Heckel	
Alburnus alburnus (Linné, 1758)	Cyprinidae	Bleak	Ablette	Abiot, Ablet, Aublet, Blanchaille, Blanchet, Douzai, Douzain, Ovelle, Auble, Blison, Dormelle
Barbus barbus (Linné, 1758)	Cyprinidae	Barbel	Barbeau fluviatile	Barbillon, Barberin
Rhodeus amarus (Bloch, 1782)	Cyprinidae	Bitterling	Bouvière	Péteuse, Rosière
Blicca bjoerkna (Linné, 1766)	Cyprinidae	White bream	Brème bordelière	Petite brème, Harriot, Henrriot, Blike
Abramis brama (Linné, 1758)	Cyprinidae	Fishwater bream	Brème commune	Hazeau, Brenne
Hypophthalmichthys molitrix (Valenciennes, 1844)	Cyprinidae	Silver carp	Carpe argentée	
Carassius carassius (Linné, 1758)	Cyprinidae	Crucian carp	Carassin	Carasche, Carreau
Carassius auratus (Linné, 1758)	Cyprinidae	Goldfish	Carassin doré	Daurade de Chine, Cyprin doré, Poisson-rouge
Carassius gibelio (Bloch, 1782)	Cyprinidae	Prussian carp	Carassin argenté	Carpe Gibèle
Cyprinus carpio (Linné, 1758)	Cyprinidae	Common carp	Carpe	Kèrpaille, Kèrpe
Squalius cephalus (Linné, 1758)	Cyprinidae	Chub	Chevaine	Meunier, Juène, Catis, Cabeda, Able meunier, Cavergne, Cheneviot, Cherverne, Momer, Rotisson, Vilain, Vilna, Vilnachon
Rutilus rutilus (Linné, 1758)	Cyprinidae	Roach	Gardon	Roche, Gardon rouge, Gardon blanc, Rousseau, Able rosse, Rosse, Rossat, Rousse, Ryssling
Gobio gobio (Linné, 1766)	Cyprinidae	Gudgeon	Goujon	Goiffon, Goiffou, Goujin, Goffi, Jol, Tragnan, Chabroua
Chondostroma nasus (Linné, 1758)	Cyprinidae	Common nase	Hotu	Aloge, Alonge, Allonge, Ame noire, Seufle grise, Seuffre, Écrivain, Nez, Mulet, Nase
Leusicus idus (Linné, 1766)	Cyprinidae	Ide	Ide mélanote	
Scardinius erythrophtalmus (Linné, 1758)	Cyprinidae	Rudd	Rotengle	Charin, Roche, Rosse, Rochard, Gardon rouge, Rousseau
Alburnoides bipunctatus (Bloch, 1782)	Cyprinidae	Chub	Spirlin	Able grise, Éperlan de Seine, Épelan de Seine, Able bordé, Able brodé, Able rayé, Lignotte, Lugnotte, Lorette, Lurette, Louvotte, Rieland

Table II. - Continued.

Species	Family	English common name	French common name	French local name
Phoxinus phoxinus (Linné, 1766)	Cyprinidae	Eurasian minnow	Vairon	Arlequin, Beuzou, Véron, Woéron, Gravier
Leuciscus leuciscus (Linné, 1758)	Cyprinidae	Common lace	Vandoise	Seuffe, Gravelet, Ventoise
Misgurnus fossilis (Linné, 1758)	Cobitidae	Weatherfish	Loche d'étang	Misgurne, Grande kerliche, Palmo
Cobitis taenia (Linné, 1758)	Cobitidae	Spine loach	Loche de rivière	
Barbatula barbatula (Linné, 1758)	Nemacheilidae	Stone leach	Loche franche	Barbotte, Barbette, Barbillon , Barbotin, Loque, Enmantelle, Mantelle
Ameiurus melas (Rafinesque, 1820)	Ictaluridae	Black bullhead	Poisson-chat	
Silurus glanis (Linné, 1758)	Siluridae	Wels catfish	Silure	
Esox lucius (Linné, 1758)	Esocidae	Northern pike	Brochet	Aiguillon, Bécot, Bécquet, Bec-de-canne
Osmerus eperlanus (Linné, 1758)	Osmeridae	Pond smelt	Éperlan	Épelan
Coregonus lavaretus (Linné, 1758)	Salmonidae	European whitefish	Corégone	Féra, Ferra, Lavaret
Coregonus clupeoides (Lacépède, 1803)	Salmonidae	Powan	Corégone	
Salvelinus umbla (Linné, 1758)	Salmonidae	Artic char	Omble chevalier	Ombre
Thymallus thymallus (Linné, 1758)	Salmonidae	Grayling	Ombre commun	
Salmo salar (Linné, 1758)	Salmonidae	Atlantic salmon	Saumon atlantique	Bécard, Saumon Rille
Oncorhynchus tshawytscha (Walbaum, 1792)	Salmonidae	Chinook salmon	Saumon quinnat	Quinnat, Saumon de Californie
Salvelinus fontinalis (Mitchill, 1815)	Salmonidae	Brook trout	Saumon de fontaine	Truite de fontaine
Oncorhynchus mykiss (Richardson, 1836)	Salmonidae	Rainbow trout	Truite arc-en-ciel	
Hucho hucho (Linné, 1758)	Salmonidae	Huchen	Huchon	
Salmo trutta fario (Linné, 1758)	Salmonidae	Brown trout	Truite fario	Truite de rivière, Truite saumonée, Truitie
Lota lota (Linné, 1758)	Gadidae	Burbot	Lote	Moustèle, Moutelle, Barbote, Barbotte, Chatoille, Alote
Gasterosteus gymnurus (Cuvier, 1729)	Gasterosteidae	Three-spined stickleback	Epinoche	Picot, Savenier, Estrangla, Darselet, Arselet, Épingale
Pungitius laevis (Cuvier, 1829)	Gasterosteidae	Ninespine stickleback	Epinochette	Marichand
Liza ramada (Risso, 1826)	Mugilidae	Thinlip grey mullet	Mulet porc	Muge capiton
Gymnochephalus cernuus (Linné, 1758)	Percidae	Ruffe	Grémille	Perche goujonnière, Perche goujonnée, Grenillet, Perche à goujon, Chagrin, Grimon
Perca fluviatilis (Linné, 1758)	Percidae	European perch	Perche	Perco, Hurlin, Perchat, Perchelle
Sander lucioperca (Linné, 1758)	Percidae	Pike-perch	Sandre	Sandat
Micropterus salmoides (Lacepède, 1802)	Centrarchidae	Largemouth black bass	Black-bass	
Lepomis gibbosus (Linné, 1758)	Centrarchidae	Pumpkinseed	Perche-soleil	
Cottus perifretum (Linné, 1758)	Cottidae	Bullhead	Chabot	Têtard, Séchot, Bavard, Chaboisseau, Chabaou, Bânes, Cafard, Jacquard, Cabot, Chamsot, Sabot, Sabotier, Chapsot, Chafaux, Caborgne

Table II. - Continued.

Species	Family	English common name	French common name	French local name
Platichthys flesus (Linné, 1758)	Pleuronectidae	European flounder	Flet	
Austropotamobius pallipes (Lereboullet, 1858)	Astacidae		Écrevisse à pieds blancs	
Astacus astacus (Linné, 1758)	Astacidae		Écrevisse à pieds rouges	Écrevisse commune, Cancre, Craibosse, Creuviche, Creuvisse, Écrebisse, Équeurvisse, Greuche
Orconectes limosus (Rafinesque, 1817)	Cambaridae		Écrevisse américaine	

Hydrographical references and geographical information

In the database, each fish observation was associated with a corresponding water body described by three characteristics: the watershed (in this case, the Seine River basin), the water body name, and the water body type (river, pond, canal). The name of the water body was included as it was reported in the historical source. Because of the wide heterogeneity of geographic scales used in historical sources, it was not possible to propose a unique scheme to satisfactorily describe locations for all observations. Therefore, we used four levels to specify the spatial location of the observations. The coarser level is the region and the database includes a pull-down list of the regions in the Seine basin. When possible, we also noted the department and the nearest city or village. Some of the observations correspond to a specific location or to a river reach with defined upstream and downstream limits. This is the most precise geographical information in the database. We also used a free entry data field for other geographical information that cannot be included in the four previous fields.

Temporal information

A date was given in the database for each reference and corresponds to the date of the fish observation. All the dates were recorded under the format dd/mm/yyyy. The date of observation was rarely given with precision in the historical record. In such cases, the "observation date" field registers the date with as much precision as possible. For instance, if a fish was observed in May 1840, we used 01/05/1840 and if a species was observed in 1878, we used 01/01/1878. When the observation lacked any date, we used the publication date, which is specified in the field "Type of date". A pull-down list (exact date, period, date of knowledge, publication date, and first and last observation dates) gives the different types of information.

To complete the field "observation date" and to detail dating information, we used a "temporal detail" pull-down list (exact date, exact month and year, exact year, several year range, decade, and century).

Biological and ecological information

The presence or the absence of fish taxa is the key information field in CHIPS. Information related to species abundance was also included when available in the archives. The reason for the presence or absence of a species (stocking, introduction, extinction) was indicated where possible.

Details about the characteristics of the river reach as they relate to fish ecology were also noted. These details are particularly useful for migratory fish as they provide information such as location of spawning grounds, growth areas, and upstream migration limits.

Most of the historical archives contained complementary ecological or biological information. Because of their considerable variability, it was not possible to include them in the main database. However, we did keep this information in a field where we noted if the historical source included supplementary data, such as fish ecology (particularly spawning dates), biometry (fish size), catch number, and fish health.

Type of data and reliability

Observations are often recorded in reports and public inquiries. In CHIPS, they were separated into three categories: (1) catch/direct observation documented by an observer: the observation is considered to be quite reliable; (2) inquiry/summary: for example, an official inquiry that collects information from observers. In the data field "Other information", we indicated if it was either a catch or an observation; and (3) story or account: a second-hand account told to the author but not verified. This information may not be accurate.

To indicate the accuracy of each observation, we added a field called "Observation quality" that is based on our assessment of data reliability. It takes into account the taxa identification, the spatial location, and the observation date. There are four categories: (1) accurate data: taxa identification, location, and date are precisely given; (2) partially accurate data: location and/or date are given with some vagueness; (3) possible inaccuracy: where we have reasons to doubt the

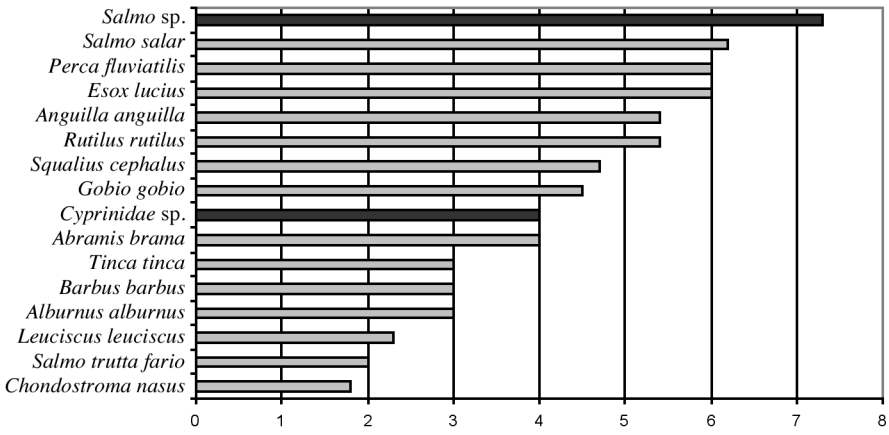

Figure 2. - Main species in the database (% of observations). Black bars refer to taxa identification higher than species level.

taxa identification, location or date; and (4) incorrect data: where an observation is clearly inaccurate.

Possible links with other databases

The Sandre (Service d'administration nationale des données et référentiels sur l'eau) of Onema develops water reference data sets to promote exchanges between the French producers of public water data. In order to enable future data interchange with such databases developed by Onema and improve the CHIPS database accessibility for a larger audience, we used the same taxonomic codes and references.

RESULTS AND DISCUSSION

Present stage of the database

A total of 4283 observations were collected in historical archives and included in the database. Absence of a taxa accounted for about 5% of observations. Presence/absence data had some indications of species abundance for a quarter of the observations.

Even though published sources represented less than the half of the documents (Fig. 1), they resulted in approximately three quarters of the observations. In terms of data quantity, published sources contained the largest part of the data. However, handwritten archives frequently provide obscure or totally new information. This was especially true in governmental archives for migratory and commercial species (for examples, see the questionnaires referenced in the "Material and methods" section).

About 5% of the observations reported fish restocking activities (about 1% for species introduction attempts and 2% for extinction events). Additional information about fish ecology (13%), biometry (14%), catches (8%), and fish health (less than 1%) was also available in archive sources.

Species and taxa

In total, 58 species or taxa were identified (Tab. II). They included the following families (with the number of species in parenthesis): Petromyzontidae (3), Acipenseridae (1), Anguillidae (1), Clupeidae (2), Cyprinidae (22), Cobitidae (2), Nemacheilidae (1), Ictaluridae (1), Siluridae (1), Esocidae(1), Osmeridae (1), Salmonidae (11), Gadidae (1), Gasterosteidae (2), Mugilidae (1), Percidae (3), Centrarchidae (2), Cottidae (1) and Pleuronectidae (1) and for crayfish Astacidae (2) and Cambaridae (1). The two most diverse families in the Seine basin are the Cyprinidae (37%) and the Salmonidae (18%).

The species most frequently observed were those common in the Seine basin and preferentially caught by fishermen and also in aquaculture (Fig. 2). This is the case for the trout (mix of taxa), which accounts for more than 7% of all observations, *Salmo salar* Linnaeus, 1758, *Perca fluviatilis* Linnaeus, 1758, and *Esox lucius* Linnaeus, 1758. *Anguilla anguilla* (Linnaeus, 1758) has a protection designation that has changed over time, including a high value species, a partially protected species or a pest species. During the last two centuries, restocking measures and eradication campaigns have both been conducted for *A. anguilla*. Between 1870 and 1890, young *A. anguilla* were released into many rivers in the Seine basin. In 1888, in the Department of Aube, 190 000 *A. anguilla* juveniles were reintroduced into rivers[4]. In 1877, thousands of *A. anguilla* were stocked in small tributaries of the lower Seine River (particularly in the Cailly, Robec, and Lézarde rivers) in order to maintain populations[5]. In 1964, *A. anguilla* was declared by decree to be undesirable in salmonid rivers and extensive destruction of populations was undertaken over nearly twenty years. Finally, in 1985,

[4] AN F[14] 13609: Department of Aube, Ponts et Chaussées engineer report, 1889

[5] AN F[14] 13609: Department of Seine inférieure, Ponts et Chaussées engineer report, 1879

Table III. - Principal waterbodies.

Major streams	Data (%)
Seine	23.0
Yonne	7.5
Marne	6.7
Oise	3.5
Armançon	3.2
Eure	3.2
Bourgogne canal	3.1
Loing	3.0
Vanne	2.5
Others	44.3

A. anguilla was removed from the French list of pest species (Boude *et al.,* 2007) and the species is now protected throughout Europe (Anonyme, 2010).

Space and time

Data from more than 220 water bodies were recorded. Most data were from rivers (80%). The rest was divided between ponds (12%) and canals (8%). The Seine River was the water body the most cited in historic sources (23%) (Tab. III). Major tributaries such as the Yonne, Marne, and Oise rivers and, to a lesser extent, the Eure and Loing rivers were also cited. There were also some observations from smaller streams (Fig. 2).

About twenty canals were identified in the documents. The two major ones were the Bourgogne Canal (35%) and the Nivernais Canal (15%), both in the Bourgogne region. There were also many observations for ponds, which were significant fishing reserves for anglers and fish farmers.

The data cover a large part of the Seine basin and all the major rivers are mentioned (Fig. 3).

A large part of the data was assigned to the regional scale (93%) [30% in Bourgogne, 20% in Champagne-Ardenne, 19% in Île-de-France, 16% in Haute-Normandie, 6% in Picardie, and 2% in Centre], and at the departmental scale (85%). Fifty-eight percent of data was associated with a city or a village, but only 7% was precisely located on a river reach (or a lake or pond).

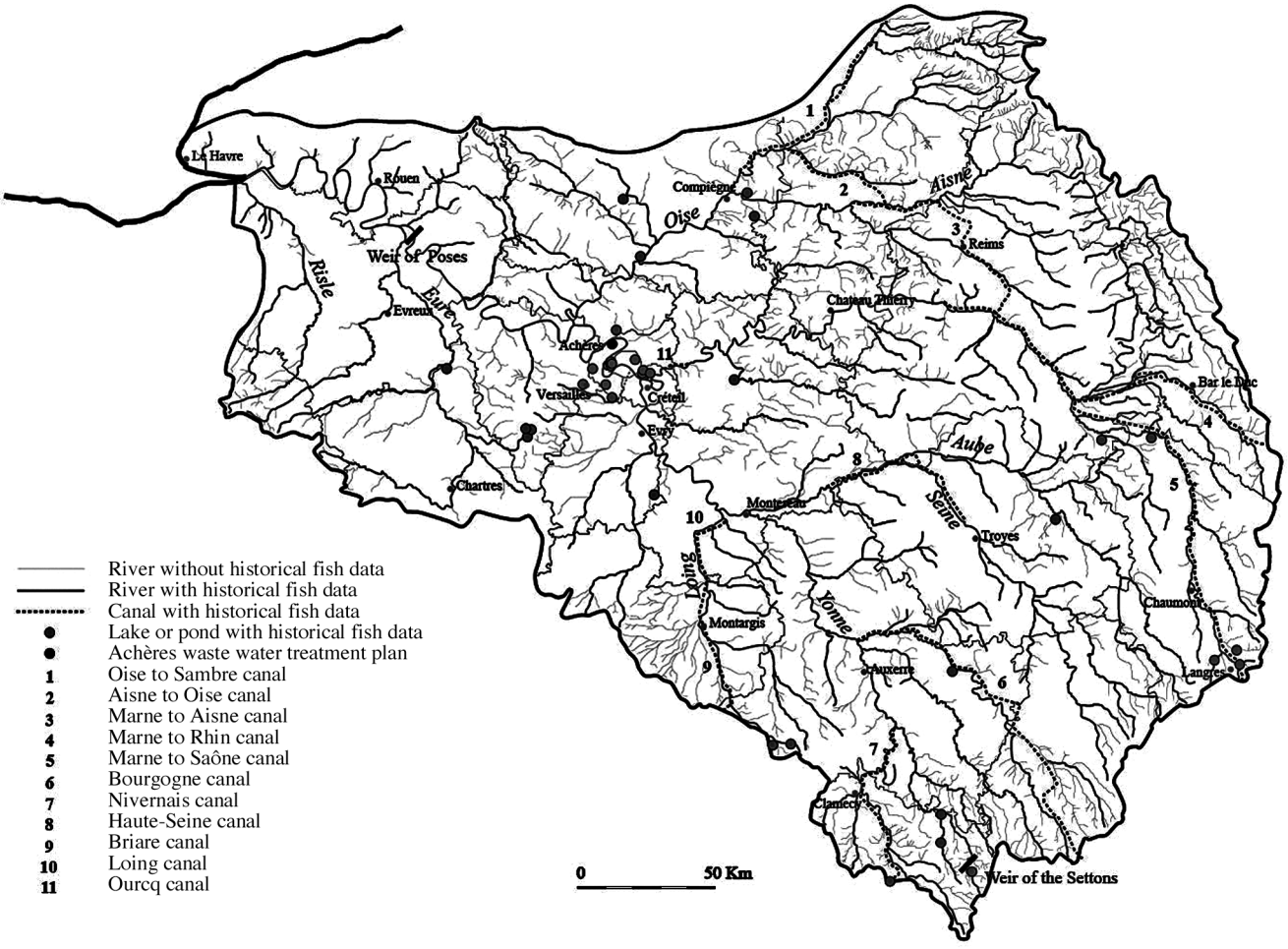

Figure 3. - Waterbodies with historical fish data.

Table IV. - List of non-native species present in the Seine basin. The first observation date corresponds to the oldest date mentioned in the CHIPS database. Dates of introduction cited in the literature are mainly extracted from Belliard (1994), Boët *et al*. (1999) and Keith and Allardi (2001). * dates corresponding to the Seine basin.

Non-native species	First observation date	Date of introduction in the Seine basin or in France cited in the literature
Carassius carassius (Linné, 1758)	1868 (De La Blanchère, 1868)	18th century
Carassius auratus (Linné, 1758)	1843 (Ray, 1843)	18th century
Carassius gibellio (Bloch, 1782)	1843 (Ray, 1843)	20th century
Cyprinus carpio (Linné, 1758)	1851 (Ray, 1851)	Middle ages
Chondrostoma nasus (Linné, 1766)	1860 (Moreau, 1898)	About 1860
Hypophthalmichtys molitrix (Valenciennes, 1844)	1948 (Elluin, 1948)	In the last part of the 20th century
Leucaspius delineatus (Heckel, 1843)	1946 (Spillmann, 1961)	20th century
Leuciscus idus (Linné, 1766)	1864 (Bert, 1986)	About 1995
Ameirus melas (Rafinesque, 1820)	1871 (Jeunet, 1894)	1871
Silurus glanis (Linné, 1758)	1875 (Millet, 1875)	About 1980
Oncorhynchus mykiss (Richardson, 1836)	1893 (AN F* 13611-Jacob, 1896)	About 1880
Oncorhynchus tshawytscha (Walbaum, 1792)	1878 (Jeunet, 1891)	1877 in France
Salvelinus umbla (Linné, 1758)	1863 (F* 6048-1869)	Autochthonous in France, in the Alps
Salvelinus fontinalis (Mitchill, 1815)	1885 (Vacher, 1892)	About 1880
Hucho hucho (Linné, 1758)	1864 (AN F* 13595-Coste, 1864)	In the last part of the 20th century in France
Thymallus thymallus (Linné, 1758)	1965 (Spillmann, 1965)	About 1960
Coregonus lavaretus (Linné, 1758)	1861 (Roger-Desgenettes, 1863)	Autochthonous in France, in the Alps
Coregonus clupeoides (Lacepède, 1803)	1893 (De Confévron, 1893) (disappear)	In the last part of the 20th century in France
Gymnochephalus cernuus (Linné, 1758)	1797 (Lacombe, 1797)	In the beginning of 18th century
Sander lucioperca (Linné, 1758)	1827 (Baudrillart, 1827)	About 1960
Lepomis gibbosus (Linné, 1758)	1948 (Elluin, 1948)	About 1885
Micropterus salmoides (Lacepède, 1802)	1904 (Roger, 1906)	About 1890

Because we focused our archival research on the modern period, a large majority of data (98.5%) was from the 19th and 20th centuries. In anticipation of a probable, future, temporal extension of our database, older data were occasionally recorded in CHIPS. The oldest ones date back to the 16th century.

Data type and reliability

More than 90% of the collected data was classified as inquiry/summary. Five percent were direct observations or catches, and the remaining data (4%) were stories and second-hand accounts.

Most references (90%) were considered to be accurate. Only 10% were partially accurate or uncertain. These last two categories contained stories or second-hand accounts and, in some cases, were observations on extinction. Authors may have confused extinction of a species with its absence in a given river or location. Data in these two categories should be used with caution.

Preliminary analysis of the database

During the past two centuries, 58 species or taxa have been identified in the Seine basin (Tab. II). Species for which the distribution seems to have changed the most are migratory fish. Several species became extinct in the beginning of the 20th century. Introduced species distribution changed with on-going colonization of the Seine River system.

Non-native species

Twenty-two non-native species were referenced in the Seine River system (Tab. IV). The introduction method varied, as well as the species' country of origin. Some species were introduced by man and others colonized the basin using canals connecting catchments (Nelva-Pasqual, 1985; Boët *et al*., 1999).

The rediscovery by Remy and Gehin in 1842 of the artificial reproduction of trout (Haxo, 1853) and the creation of the first fish breeding institution at Huningue (Haut-Rhin) responsible for egg distribution to restock French rivers, in 1853, played a major part in planned fish introductions (Keith *et al*., 2011).

For several non-native species, there were contradictions between the date of the first observation in the historical record and the date cited in the literature for their introduction in the Seine basin (Belliard, 1994; Boët *et al*., 1999). For most introduced species, the observation date was several years after their known introduction date. For some others, such as *Silurus glanis* Linnaeus, 1758 and *Leuciscus idus*

(Linnaeus, 1758), some observations predate the recognised, successful introduction. It is possible that these individuals were a remnant population from previous introduction attempts thought to have failed. In 1854, the Société impériale zoologique d'acclimatation was created, whose mission was to introduce, acclimatize, and domesticate useful or ornamental species (Keith *et al*., 2011). Consequently, some fish were introduced for scientific purposes (to increase diversity of fish fauna), such as *S. glanis, L. idus, Ameiurus melas* (Rafinesque, 1820), and *Lepomis gibbosu*s (Linnaeus, 1758), and some others for commercial purposes, such as *Micropterus salmoides* (Lacepède, 1802*), Salvelinus fontinalis, Oncorhynchus mykiss,* and *O. tshawytscha* (Walbaum, 1792). These last species originally came from North America and were introduced into French rivers during the 19th century to increase stocks, and were much valued by French fishermen. This introduction coincided with the development of angling as a sport. For some species, especially salmonids, introduction attempts did not result in established populations (e.g. *O. tshawytscha, Salvelinus umbla* (Linnaeus, 1758), and *Coregonus* sp.). Others are still present in the basin today, probably due to continuous stocking practices (e.g. *S. fontinalis* and *O. mykiss*). The cases of *S. glanis* and *L. idus* illustrate that, for some species, repeated introduction was necessary before permanent populations became established.

There have also been some unplanned introductions, notably of *Sander lucioperca* (Linnaeus, 1758) and *Chondrostoma nasus* (Linnaeus, 1758). In the beginning of the 19th century, Baudrillart (1827) noted the presence, though very rare, of *S. lucioperca* in the Seine River. This first mention for the Seine catchment is based on an account that could not have been checked by the author. The first catch in France was documented much later, in 1888, in the river Rhine (Armengaud, 1962 *in* Keith *et al*., 2011). At the beginning of the 20th century, this species from central Europe extended its range to the west and the south, colonizing the canals connecting the Rhine River to the Marne and Rhône Rivers (Spillmann, 1961). Around 1950, the colonization of Seine basin was confirmed and even if canal connections between catchments were major colonization pathways, stocking promoted by French fisheries associations, considerably favoured the establishment of sander (Goubier, 1975). *C. nasus* is a similar example. It is probable that many fish species used the canals

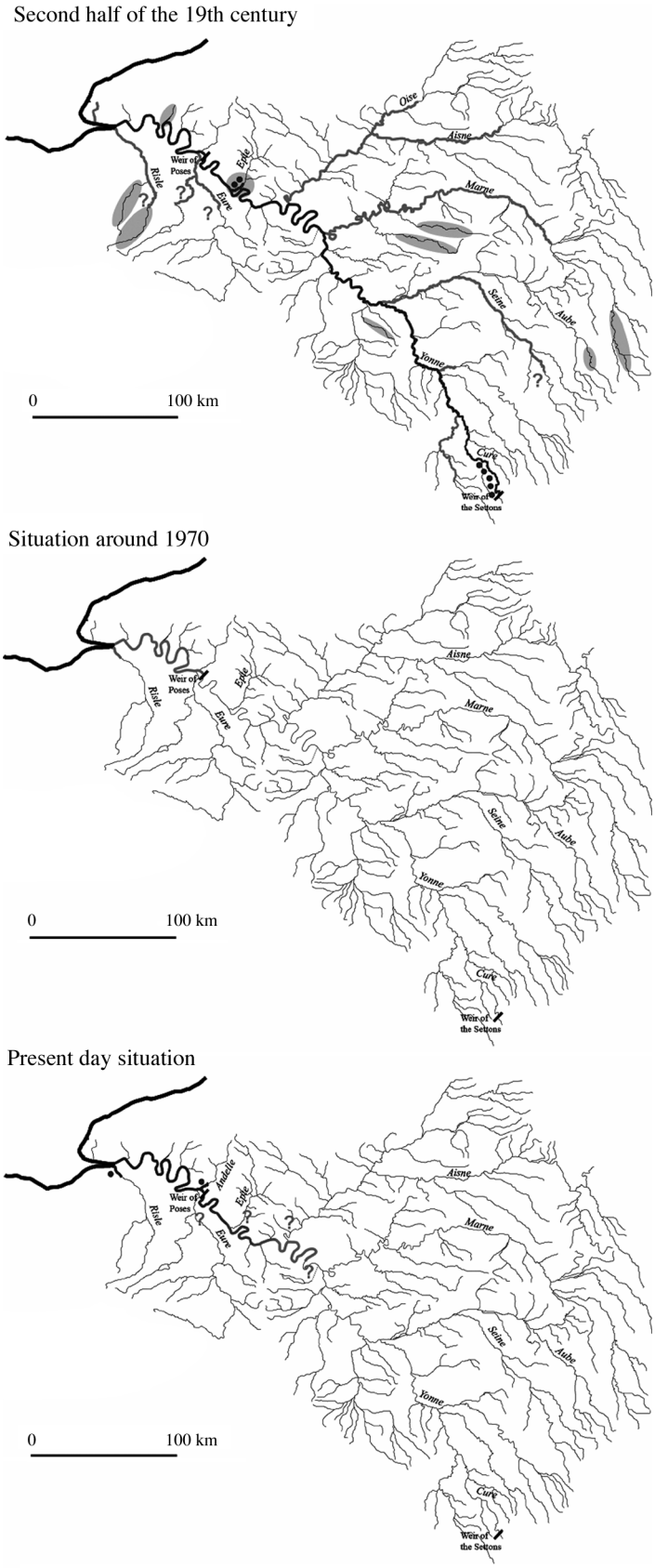

Figure 4. - Distribution changes of *Salmo salar* in the Seine basin during the last two centuries.
▬ Main migratory axis; • • • • Location of active spawning grounds; ▬ Sporadic salmon observations; ⬬ Stocking attemps.

connecting the different European river basins to reach the Seine basin (Nelva-Pasqual, 1985).

Evolution of migratory fish distribution: the case of Salmo salar

Little is known about the early distribution of *S. salar* in the Seine River basin. During the 19th century, spawning grounds were recorded only in some small tributaries of the Seine River estuary (Gadeau de Kerville, 1897) and in the upper basin on the Cure River (Moreau, 1898; Poplin, 1952; Fig. 4). It was commonly thought that its distribution area was restricted to the Seine-Yonne-Cure axis and to a lesser extent to the mouth of the Eure, Andelle and Epte Rivers, all situated in the Haute-Normandie region (Thibault, 1987).

Even though the Seine-Yonne-Cure axis represented the main path for the migration of *S. salar* during the 19th century, our data show that the species was also observed (but in low numbers) in several other places throughout the Seine basin (Fig. 4), suggesting an earlier, larger, geographical distribution.

The cause of salmon population decline during the 19th century is often attributed to overfishing, pollution and development of reservoirs and dams in the upper basin that were built to float timber downstream (Belliard, 1994). The construction of the Settons Dam (19 m in height) on the Cure River was completed in 1858 and closed access to upstream spawning grounds (Moreau, 1898). The weir at Poses located in the estuarine part of the Seine River was put in service in 1885. It also contributed to the decline of migratory species. In the beginning of the 20th century, the fish catch of *S. salar* was only several tens of kilograms per year. During the same period, it was about 57 tons per year in the Loire basin (Euzenat *et al*., 1992).

Canalization of rivers for navigation purposes began in 1830 in the centre of the basin and later extended to the lower Seine River basin. It progressively increased the number of barriers to fish migration (Lavollée, 1902). A second phase of river canalization, starting in 1879, resulted in higher weirs and lock systems. This precipitated the decline of migratory stocks, particularly for *Salmo salar* (Mouchel *et al.,* 1998; Belliard *et al*., 2009). During the same period, domestic and industrial pollution from Paris led to the progressive degradation of water quality in the lower Seine that introduced a new and important negative pressure on migratory fish populations (Lavollée, 1902; Belliard *et al*., 2009).

Our data also highlight the underestimation of the widespread use of stocking starting in the second part of the 19th century. Stocking with eggs or fingerlings was implemented in many places in the basin (Fig. 4), including places with no historical record of native salmon populations. Stocking did not result in permanent populations.

Despite stocking and several attempts to reduce the negative impact of dams, the populations of *S. salar* declined progressively, resulting in their extinction at the beginning of the 20th century. However, relict populations may have persisted later in some tributaries in the estuarine part of the Seine. Between 1867 and 1895, a mean of two tons (0.4-10.5 tons) of *S. salar* was still caught annually in fisheries in the Rouen region. Between 1896 and 1919, the total annual catch of *S. salar* fell to a few tens of kilograms in the same reach (Euzenat *et al.,* 1992). In 1902, *S. salar* migrations still occurred but to a much-diminished extent (Lavollée, 1902) and, in 1920, regular migrations had definitively stopped along the Seine-Yonne-Cure axis (Roule, 1920). After the extinction of *S. salar* as a breeding population, the Seine estuary still remained an attractive area for large salmonid fish (sea trout and, to a lesser extent, *S. salar*), even during the 1960's when the pollution level was at its highest (Arrignon, 1967). No new upstream salmon migration was observed until very recently (Perrier *et al*., 2010).

In 1970, anoxic events occurred at the waste water treatment plant at Achères located just downstream of Paris resulting in the elimination of several migratory fishes (Belliard *et al.,* 2009; Rochard *et al.,* 2009). Since the end of the 1990's, several migratory fish species extirpated from the Seine catchment during the 20th century have undergone natural re-colonisation. This results directly from the on-going improvement of water quality in the lower part of the Seine River (Belliard *et al*., 2009). Today, *S. salar* swims up the Seine at least to downstream of Paris. In 2008, 260 specimens of *S. salar* were counted at the Poses fish pass and some spawning grounds have been identified in small tributaries of the estuarine part of the Seine River, particularly in the Andelle and Risle catchments.

Local assemblage evolution: three examples from the "Département de l' Yonne" (Seine basin)

We studied change in the fish community composition in the three river reaches, for which historic species abundance was the most precisely documented at the end of the 19th century (Fig. 5). The historical data are from Moreau (1897, 1898), who specifically described fish species presence and abundance for several rivers and streams in the "Département de l'Yonne" at the end of the 19th century. Current fish data are from numerous electrofishing sampling events. To facilitate the comparison between historical and electrofishing data, the abundance of a fish was coded from 1 to 5. Historical data were coded 1 for a species documented as "rare" or "very rare", 2 for "quite rare" or "uncommon", 3 for "somewhat", 4 for "common", and 5 for "very common". To assess present day species abundance, we used a recent set of electrofishing data from the same river reaches. A species was coded 1 when it was infrequently sampled with a low population density, and was coded 5 when it was systematically sampled with a high population density (intermediate situations were coded 2, 3 or 4, depending on species occur-

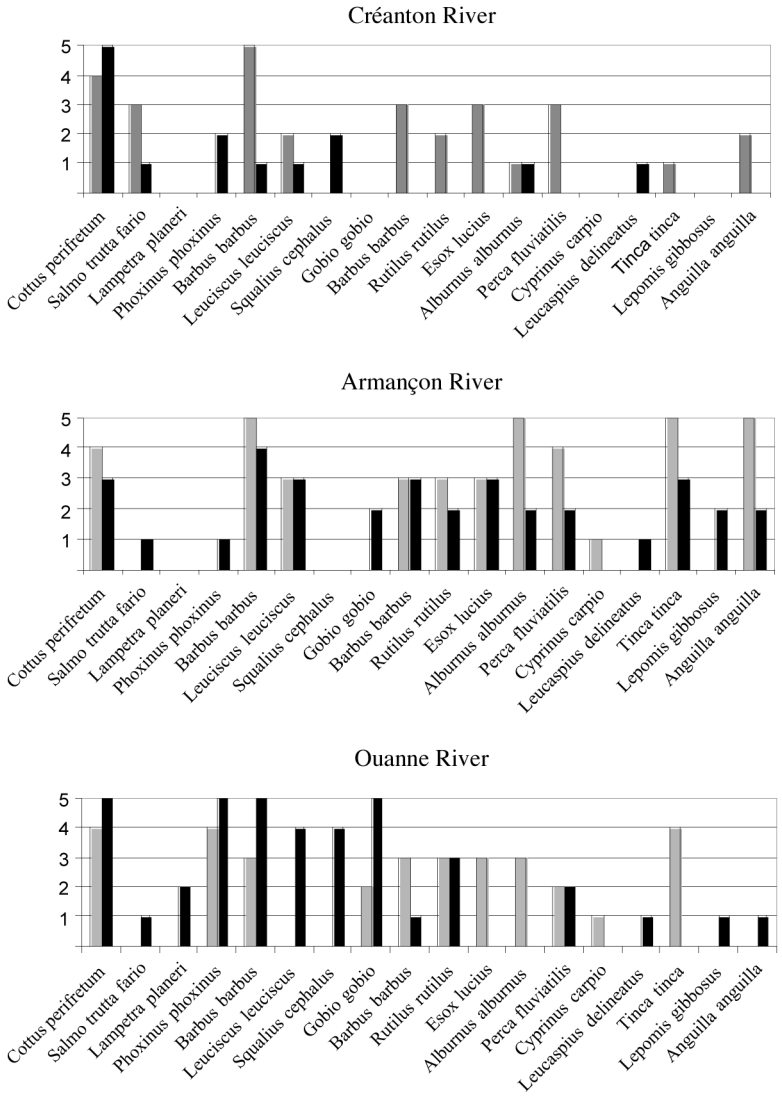

Figure 5. - Species abundance for three rivers: Créanton River (top), Armançon River (middle), Ouanne River (bottom); in grey: historical data, in black: actual data.

rence and density). We are aware that these two methods of assessing species abundance are probably not totally equivalent. However, we think they are useful for highlighting major changes in fish assemblage composition.

Between the end of the 19th century and the decade 2000-2010, the fish assemblage changed considerably in the Créanton River, the smallest river, with a significant reduction of limnophilic species (preferring slow flowing conditions). In the Ouanne River, the proportion of rheophilic species (preferring high flow conditions) increased [e.g. *Salmo trutta fario* Linnaeus, 1758, *Lampetra planeri* (Bloch, 1784), *Leuciscus leuciscus* (Linnaeus, 1758) and *Squalius cephalus* (Linnaeus, 1758)]. In the Armançon, which is the largest river of the three, the distribution remained about the same.

At this point no definitive conclusion can be drawn to explain the fish community change observed in smaller streams. Instead, we propose hypotheses about both large spatial scale and local processes. If climate warming has had a significant impact on the fish population at these sites, we might note a general increase in warm-water species, which was not systematically observed. Indeed, the fish community changes are different from one site to another, and it is likely that they are controlled by local factors. The local modifications of the morphology of the streams, such as channelization, with a consequent increase the river slope, and the removal of low head dams, with a consequent increase in the flow velocity and/or a reduction of the river depth, could explain the reduction of limnophilic fish species and/or the increase of rheophilic species observed in the Créanton and the Ouanne rivers. At a regional scale, reduction of lakes and ponds in the catchment area, and disruption of the connections between small streams and large rivers, which are colonisation sources for numerous fish species, may also explain the reduction in limnophilic species in the Créanton River. Recent improvement of water quality might also explain part of the change in the fish assemblage at the two smallest sites. Finally, change in the fish assemblage appeared to be more pronounced in smaller rivers, suggesting that they may have suffered more drastic environmental changes than in larger rivers. This tendency should be confirmed by further analysis on additional rivers experiencing on-going anthropogenic pressure.

CONCLUSION AND PERSPECTIVE

The CHIPS database, presented here for the first time, compiles a considerable amount of historical data from the last two centuries about fish distribution in the Seine River basin (see Annexe 1). Some data sources are well-known, classical ichthyology books, but the majority of the sources were difficult to access (particularly handwritten papers) and most information came from very detailed research in different archives and libraries. The data greatly expand our knowledge of the Seine fish fauna and its history. This database project was originally developed during interdisciplinary discussions with a variety of specialists: fish biologists and ecologists, historians, and archaeozoologists.

In the future, we plan to extend CHIPS to a broader temporal scale and, possibly, include complementary data sources, such as drawings, photographs, maps, and archaeological

data. We also plan to georeference the data in GIS in order to link each historical fish observation with a site. However, georeferencing will be a complex task, first because the location of historical fish observations can be very imprecise and second because river channels and other waterbodies have undergone considerable change during the historical time period (for example, the ponds "du Der", for which we have historical data, have now disappeared and have been replaced by a lake, "Lac du Der", which covers a much larger area).

The types of data gathered in CHIPS might be useful to environmental history specialists to better describe the evolution of aquatic environments through historical time and to understand the relationships between human societies and freshwater fish communities. Our database also makes new information available to ecologists, including such subjects as fish community response to climate change and to anthropogenic pressure over long time periods (colonization and extinction mechanisms, their impact on their environment, and conservation of endangered species). While recent climate warming is considered as a major driver for long term modifications in French river fish communities (Daufresne and Boët, 2007), preliminary analysis of some of the CHIPS data suggests, that at a local scale, other anthropogenic pressures might also be decisive. Our data may contribute to the on-going discussion on the concept of "reference conditions" that is at the centre of biomonitoring tools' development (Hering *et al*., 2010).

Finally, CHIPS is a step in the development of interdisciplinary research, a necessary, integrative approach needed to thoroughly understand how human societies have modified aquatic ecosystems over years and centuries, and also show fish communities answer to these anthropogenic pressures on the aquatic environment. Understanding these interactions will lead to improvement in fish management planning for the restoration and preservation of species and their ecosystems.

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* art. 19-21 : Pêches scientifiques (1925-1975)

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* art. 1-12 : Commissions de la pêche fluviale (1942-1949), Commissions des embouchures fluviales (1899) : questionnaire sur les migrateurs, Commissions des estuaires (1924)

* art. 32 : Pêche dans les étangs, dossiers d'affaires (1899-1941)

* art. 44 : Législation sur la pêche (1941-1961)

Versement 19920558 : environnement, direction de la pêche

* art. 1-4 : Projets de lois et décrets divers sur la pêche fluviale (1986-1939)

* art. 10-11 : Exploitation de la pêche (baux et adjudications, circulaires, correspondances (1922-1982)

* art. 18-24 : Espèces (1877-1984)

Caran

Série F^{10} : agriculture

* 4361 : Pêche dans les cours d'eau non navigables ni flottables

Série F^{14} : travaux publics

Navigation fluviale et maritime, police des eaux, hydraulique et agriculture, industrie

* 3599 : Législation sur la pêche : révision du décret du 10 août 1875

* 13595 et 13596 : Législation de la pêche (1802-1890)

* 13598 et 13599 : Applications et révisions du décret du 10 août 1875

* 13600 à 13606 et 13609 : Révision de la législation (1879-1911), Réglementation de la pêche du saumon (1832-1898), Echelles à poissons (1892-1896), Anguilles et écrevisses (1880)

* 13611 : Législation de la pêche. Pisciculture (1854-1913)

* 13613 à 13618 : Législation de la pêche, Barrages et échelles à poisson (1843-1910),

* 13620 et 13621 : Législation de la pêche. Réserves de pêche (1868-1934)

* 6048 : Service hydraulique des Ponts et Chaussées - Pêches-fluviales : comptes-rendus d'inspection (1860-1870)

* 16564 : Police de la pêche et de la navigation : réglementation de la pêche

Departmental archives (AD 27)

Série S : travaux publics et transports

14 S Pêche fluviale

* 3 : Pêche fluviale, règlements

Arrêtés de la police fluviale et de la préfecture de l'Eure, correspondances, rapports des Ponts et Chaussées

* 6 : Pêche fluviale, pisciculture

Rapports du service de la pêche des Ponts et Chaussées

Délibérations du conseil général

* 11 : Pêche sur l'Andelle et la Charentonne

Police de la pêche, rapports d'inspection des Eaux et forêts, lettres de plaintes

* 12 : Pêche sur l'Eure (1941-1950)

Rapports des Ponts et Chaussées, des Eaux et forêts, procès-verbaux d'alevinage, délits de pêche

* 13 : Pêche sur la Seine

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